Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP)

TEST REPORT #68

System Drop-in Test of N40c (R-448a) in a R04A Low and Medium Temperature Display Case

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1. Introduction:

A refrigerant performance comparison was conducted in Hussmann Corporation's test facility located in Bridgeton, Missouri. The two refrigerants used for this comparison were R-404A and N40c (R-448A). R-404A was purchased from United Refrigeration. The lower GWP refrigerant, N40c, was provided by Honeywell Corporation. Testing was conducted from June 11th 2014 to April 9th 2015.

2. Details of Test Setup:

a. Description of System

A custom refrigeration system was built to accommodate this test to minimize disruption to the day to day operation of the test facility. The system schematic diagram is shown in Figure 1. The condensing unit, shown in Figure 2, was located outside the test room and was configured with:

- Copeland Scroll compressor (Model ZF09K4E), utilizing liquid injection
- Discharge Temperature Control (DTC) valve set to open at a discharge temperature at or above 195°F
- Co-axial water cooled condenser. Chilled water for condenser was provided from process water supply.
- Liquid Receiver
- Flow regulating valve to modulate chilled water flow and maintain constant condensing pressure
- Three flow meters, measuring Liquid Injection, Display Case Suction and Compressor Suction.
- Hot Gas Bypass

The condensing unit was piped to the test unit, a Hussmann Model FW-12G display cabinet, located in a controlled ambient test room. The test unit is shown in Figure 3. The test unit was equipped with:

- Two evaporators
- Two adjustable thermal expansion valves
- Liquid to Suction line heat exchanger located inside the test unit.
- Electric defrost heaters
- Hussmann case controller to maintain constant discharge air temperatures by use of a suction stop solenoid

The test unit and test room were prepared and operated in accordance with ASHRAE 72-2005 standards.

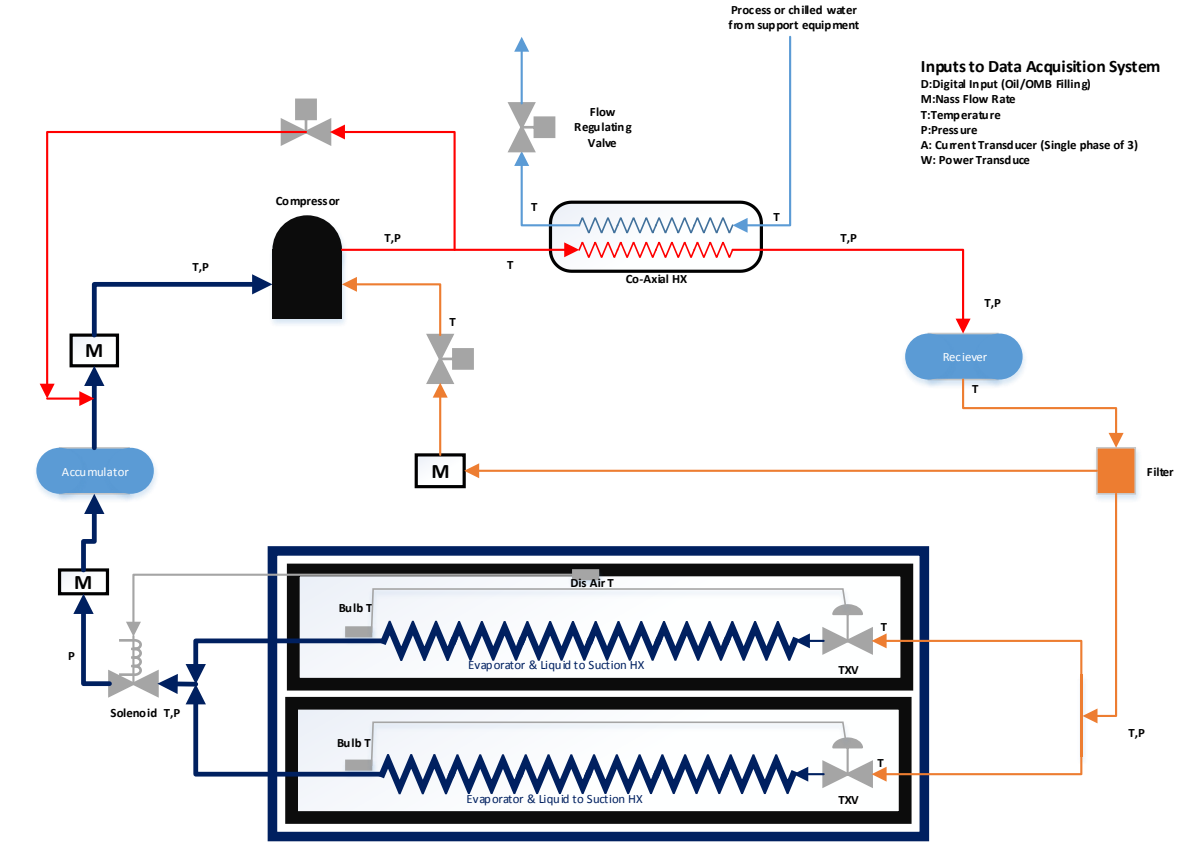

Figure 1: System Drawing

Figure 2: Condensing Unit

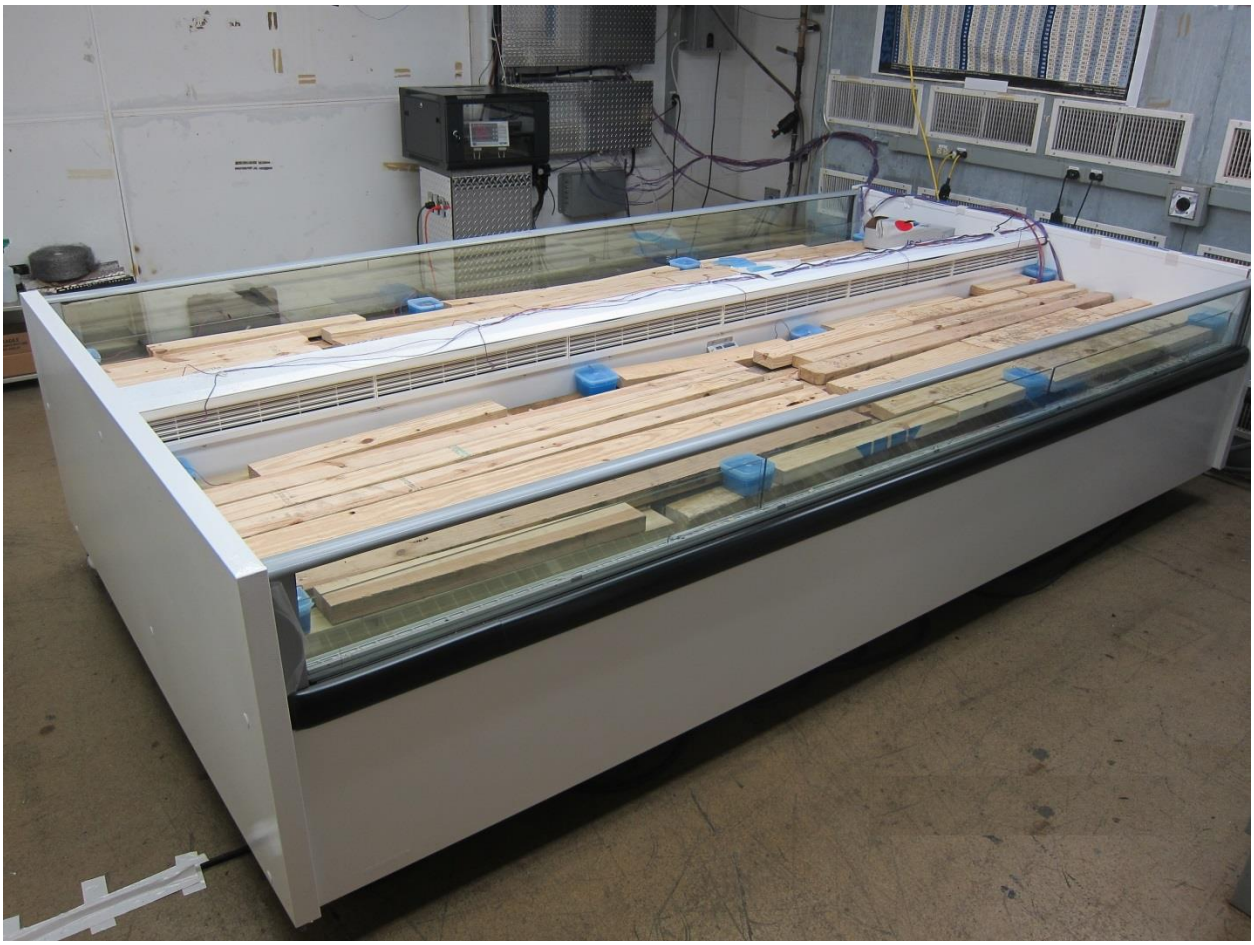

Figure 3:FW-12G Display Cabinet

b. Description of Modifications to System

The system was charged with 17.5 lbs. of R-404A and operated at low temperature with a -20°F SST setting. R-404A was then recovered, unit evaluated and recharged with 17.5 lbs. of N40c and operated at low temperature settings again. This was repeated for medium temperature, +20°F SST (Saturated Suction Temperature) setting. For the medium temperature runs, a hot gas bypass loop was used to keep the compressor running.

Process/chilled water flow and/or temperature was changed to maintain a subcooling temperature of approximately 3°R relative to bubble point.

The TXV was modified while testing with N40c to maintain superheat temperature of 6°R

It should be noted, that the temperature difference between the saturated vapor temperature and the saturated liquid temperature or "glide", for R-404A is around 1°F while for N40c the glide is between 8°F and 10°F.

c. Description of Tests Conducted

Test setup is shown in Figures 1, 2 and 3

Instrumentation:

Flow Meters: Micro Motion 2700R12BBAEZZZ ±0.5% of rate
Thermocouples: Watlow T24-2-505 Type T ±0.5°C or ±0.4%
Pressure Transducers: Schaevitz P1021-0005 ±0.20%
Noshok 200-1000-1-2-2-7 ±0.5%

The comparison between R-404A and N-40c was completed according to the test plan shown in Table 1.

Test Sequence #	Case Model #	Case Load (BTU/hr)	Case Temp Setting (°F)	Refrigerant	Test Room Conditions	Condensing Temp (°F)	Average Superheat Setting (°F)	DTC Regulating Valve Setting (°F)	Valid test #
1	FW-12G	7584	-15	R-404A	ASHRAE 72	90	6	193	13
2	FW-12G	7584	-15	R-404A	ASHRAE 72	105	6	193	12
3	FW-12G	7584	-15	R-404A	ASHRAE 72	120	6	193	11
4	FW-12G	7584	-15	R-404A	ASHRAE 72	70	6	193	6
5	FW-12G	5304	24	R-404A	ASHRAE 72	90	6	193	31
6	FW-12G	5304	24	R-404A	ASHRAE 72	105	6	193	32
7	FW-12G	5304	24	R-404A	ASHRAE 72	70	6	193	33
8	FW-12G	5304	24	R-404A	ASHRAE 72	120	6	193	36
9	FW-12G	5304	24	N-40	ASHRAE 72	90	6	193	24
10	FW-12G	5304	24	N-40	ASHRAE 72	120	6	193	22
11	FW-12G	5304	24	N-40	ASHRAE 72	70	6	193	23
12	FW-12G	5304	24	N-40	ASHRAE 72	105	6	193	20
13	FW-12G	7584	-15	N-40	ASHRAE 72	90	6	193	25
14	FW-12G	7584	-15	N-40	ASHRAE 72	70	6	193	30
15	FW-12G	7584	-15	N-40	ASHRAE 72	120	6	193	29
16	FW-12G	7584	-15	N-40	ASHRAE 72	105	6	193	27

Table 1: Drop in test plan to compare R-404A with N-40c

3. Results

a. Data Forms

AREP drop in test data forms for low temperature testing are provided in Appendix A. AREP drop in test data forms for medium temperature testing are provided in Appendix B.

b. Results

The following charts and results were created from the summary tables in Appendix C and Appendix D which were in-turn generated from raw data collection.

Chart 1 below shows the change in compressor power for each refrigerant/condensing temperature test condition. There was a reduction in power consumption noticed in every comparison test except for low temperature with 90° and 70° saturated condensing temperature. For low temperature the power reduction was around 2.5% (excluding the 90° and 70° runs) and around 4.5% for medium temperature.

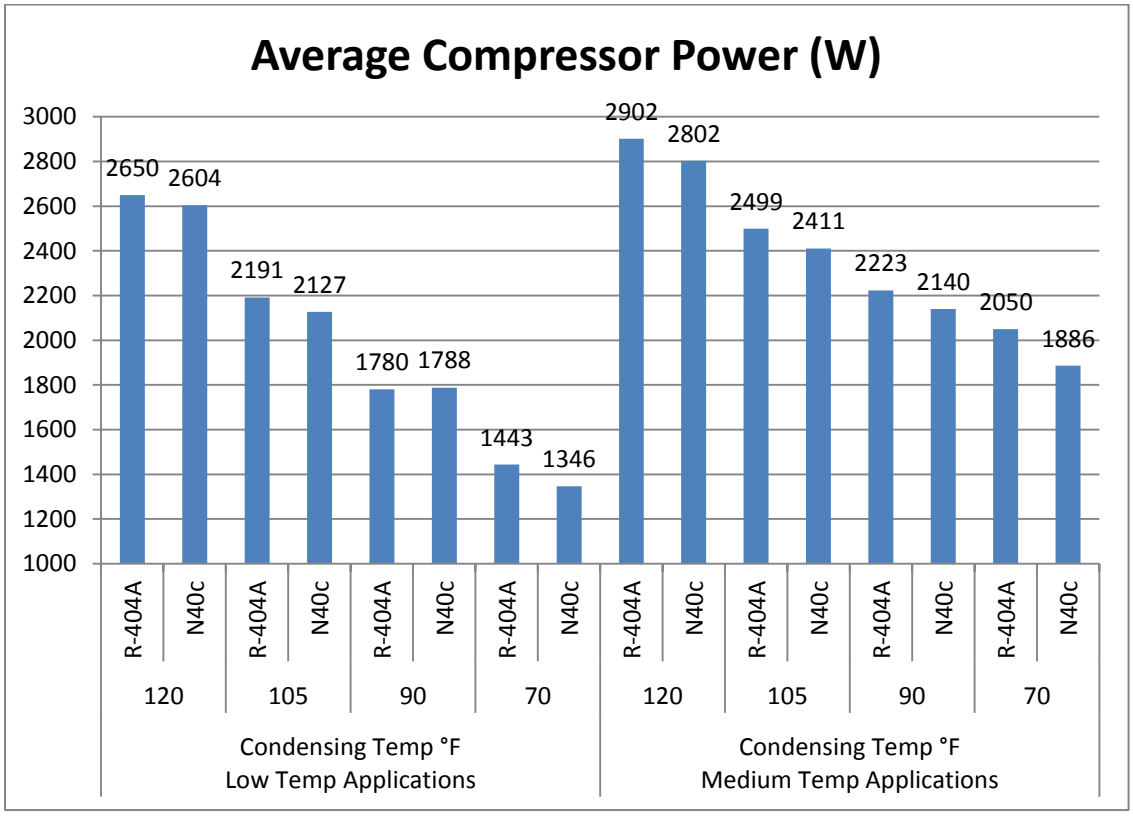

Chart 1: Compressor Power consumption R-404A vs N-40c

Chart 2 below shows the change in BTU consumption, Q Evap (BTUH), of the refrigerated cabinet for each refrigerant/condensing temperature scenario. Q Evap was calculated using the measured mass flow (lbm/hr) and multiplying it by calculated change in enthalpy (BTU/lbm) of the evaporator inlet and outlet. There was a reduction in BTUH noticed in the comparison test runs with N40c on low temp and medium temp there was a rather consistent BTUH except at 120 ambient condensing.

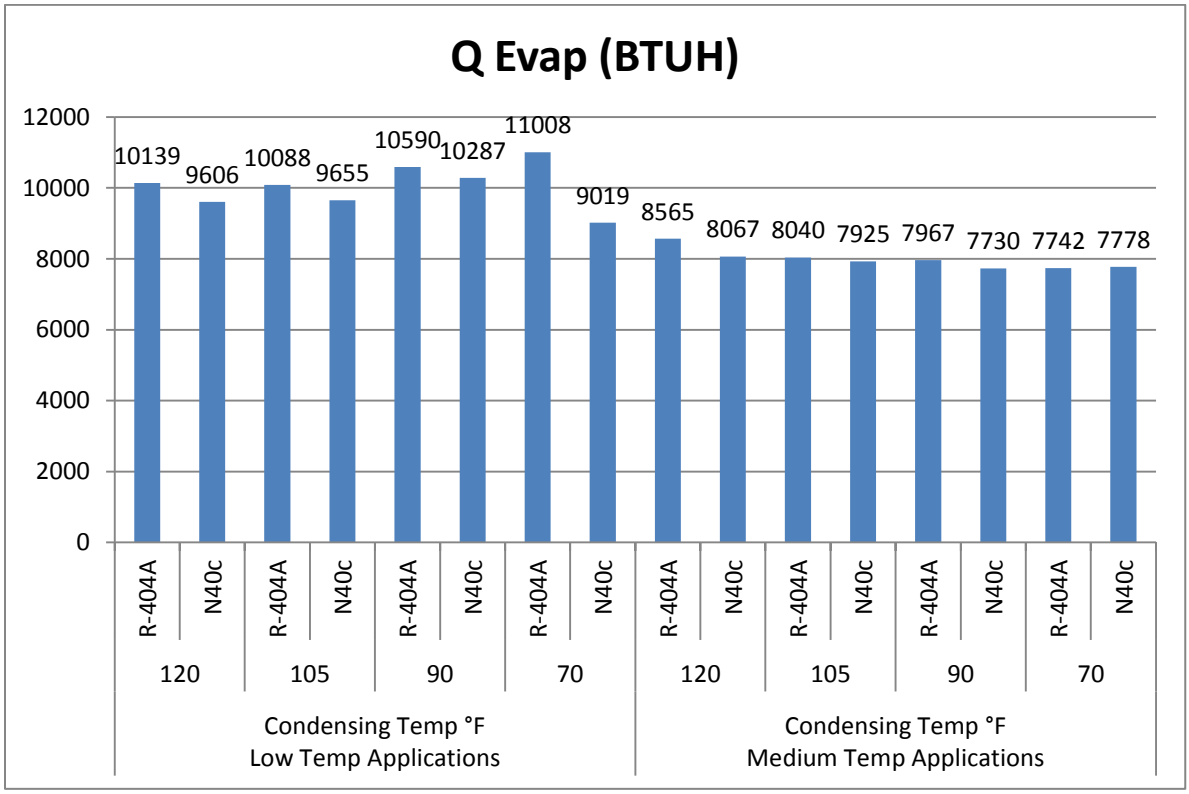

Chart 2: Display Cabinet Q BTU/hr R-404A vs N-40c

Chart 3 below shows the mass flow rate of the system for each refrigerant/condensing temperature scenario. Q Evap was calculated using the measured mass flow (lbm/hr) of the case outlet and with the difference between the case outlet and compressor inlet mass flow being the flowrate from the hot gas bypass during medium temperature runs.

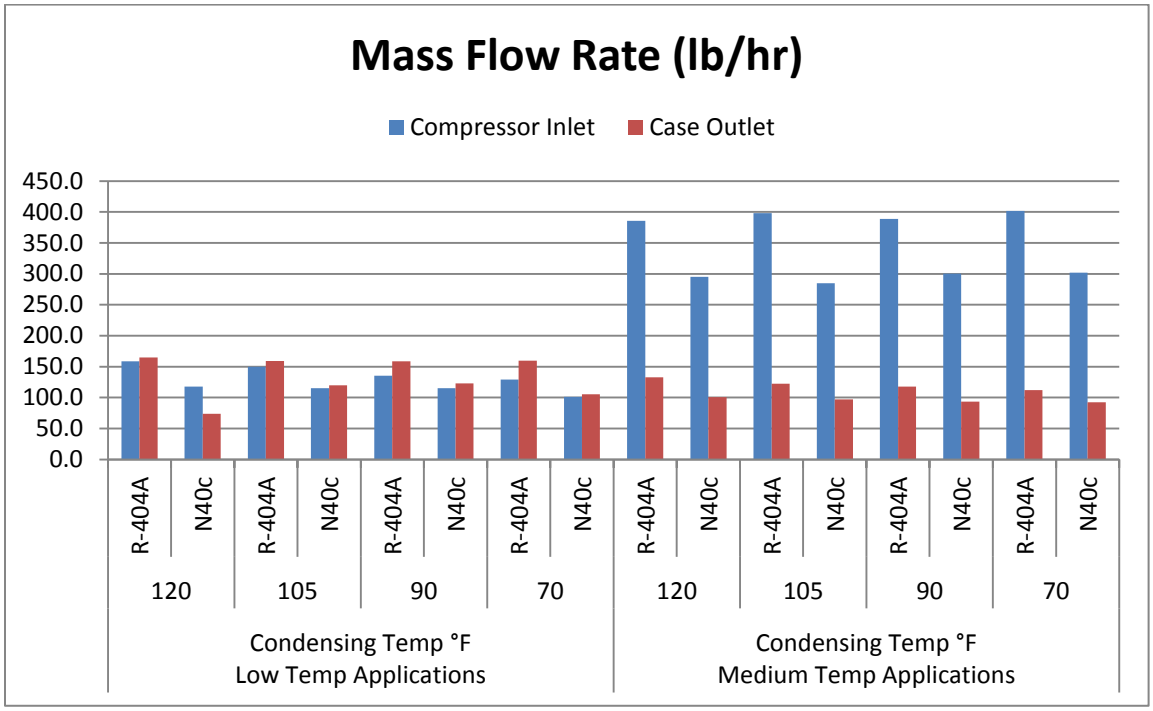

Chart 3: Mass Flow Rates R-404A vs N-40c

Chart 4 below shows the superheat out of the evaporator for each refrigerant/condensing temperature scenario. This chart shows that a consistent superheat was maintained during each test.

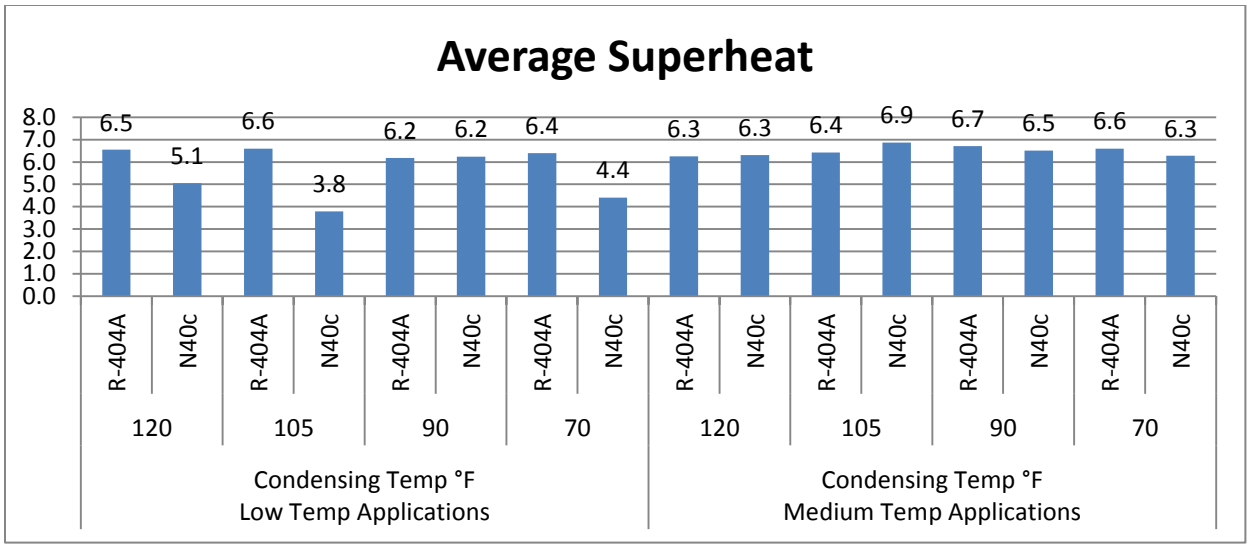

Chart 4: Average Superheat R-404A vs N-40c

c. Conclusion

While there are some things that cannot be discerned from the testing that was performed, without investing more time to re-test with another unit. Such as, why there is a capacity disparity between refrigerant side and air side for some runs. The results show that N40c is able to maintain case air discharge temperature and reduce power consumption using existing R404A equipment.

Appendix A:

Low Temperature Data

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Low Temp 70° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			0.98	0.77	kg/min	2.15	1.69	lb/min	0.78
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.01	24.42	C	75.21	75.95	F	
		wb	18.67	17.95	C	65.61	64.30	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			3226.08	2643.18	W	11007.84	9018.91	Btu/hr	0.82
Sensible Capacity					W			Btu/hr	
Total System Power Input			1555.67	1682.32	W	1555.67	1682.32	W	1.08
Compressor Power Input			1443.20	1346.00	W	1443.20	1346.00	W	0.93
Energy Efficiency Ratio (EER)			2.24	1.96	W/W	7.63	6.70	Btuh/W	0.88
Coeff. Of Performance (COP)			3.18	3.57					1.13

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio – SEER			
Heating Seasonal Performance Factor – HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	-19.80	-18.98	C	-3.64	-2.17	F	
Outlet Temperature	-24.86	-24.41	C	-12.75	-11.94	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	13.97	13.99	C	57.14	57.19	F	
Outlet Temperature	18.25	17.79	C	64.84	64.03	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	6.56	182.84	9.44	128.07	43.80	26.52	49.00	18.57
Compressor Discharge	85.22	1187.94	85.94	1065.21	185.40	172.30	186.70	154.50
Condenser Inlet	75.93	1187.94	80.57	1065.21	168.68	172.30	177.03	154.50
Condenser Outlet	19.52	1136.89	16.48	1047.47	67.14	164.89	61.67	151.92
Expansion Device Inlet	-4.89	1176.22	-4.06	1045.91	23.20	170.60	24.70	151.70
Subcooling, at expan. device	6.91		8.06		6.91		8.06	
Evaporator Inlet	-4.89	1176.22	-4.06	1045.91	23.20	170.60	24.70	151.70
Evaporator Outlet	-25.50	208.88	-18.67	226.81	-13.90	30.30	-1.60	32.90
Evaporator Superheat	6.39		4.41		6.39		4.41	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Low Temp 90° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			1.02	0.87	kg/min	2.25	1.92	lb/min	0.85
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.00	23.89	C	75.19	75.01	F	
		wb	17.81	17.57	C	64.05	63.63	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			3103.57	3014.96	W	10589.82	10287.47	Btu/hr	0.97
Sensible Capacity					W			Btu/hr	
Total System Power Input			1928.28	2046.88	W	1928.28	2046.88	W	1.06
Compressor Power Input			1780.00	1788.10	W	1780.00	1788.10	W	1.00
Energy Efficiency Ratio (EER)			1.74	1.69	W/W	5.95	5.75	Btuh/W	0.97
Coeff. Of Performance (COP)			3.12	3.87					1.24

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio – SEER			
Heating Seasonal Performance Factor – HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	-19.70	-19.66	C	-3.46	-3.39	F	
Outlet Temperature	-25.25	-25.17	C	-13.45	-13.30	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	25.27	23.85	C	77.48	74.93	F	
Outlet Temperature	30.42	28.09	C	86.75	82.56	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	8.39	181.97	9.67	154.06	47.10	26.39	49.40	22.34
Compressor Discharge	86.67	1533.37	86.17	1470.62	188.00	222.40	187.10	213.30
Condenser Inlet	80.35	1533.37	79.83	1470.62	176.62	222.40	175.69	213.30
Condenser Outlet	30.08	1504.68	27.80	1442.09	86.14	218.23	82.04	209.16
Expansion Device Inlet	-0.67	1514.75	-3.28	1454.77	30.80	219.70	26.10	211.00
Subcooling, at expan. device	5.58		9.14		5.58		9.14	
Evaporator Inlet	-0.67	1514.75	-3.28	1454.77	30.80	219.70	26.10	211.00
Evaporator Outlet	-25.78	208.88	-24.50	173.03	-14.40	30.30	-12.10	25.10
Evaporator Superheat	6.18		6.24		6.18		6.24	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Low Temp 105° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			1.13	0.87	kg/min	2.49	1.92	lb/min	0.77
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.08	24.34	C	75.34	75.82	F	
		wb	17.91	17.94	C	64.23	64.29	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2956.56	2829.70	W	10088.20	9655.32	Btu/hr	0.96
Sensible Capacity					W			Btu/hr	
Total System Power Input			2505.84	2475.09	W	2505.84	2475.09	W	0.99
Compressor Power Input			2191.00	2127.30	W	2191.00	2127.30	W	0.97
Energy Efficiency Ratio (EER)			1.35	1.33	W/W	4.60	4.54	Btuh/W	0.99
Coeff. Of Performance (COP)			2.96	4.12					1.39

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio – SEER			
Heating Seasonal Performance Factor – HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	-19.44	-18.83	C	-3.00	-1.89	F	
Outlet Temperature	-25.37	-24.26	C	-13.66	-11.67	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	25.04	23.60	C	77.07	74.48	F	
Outlet Temperature	41.17	40.68	C	106.10	105.23	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	10.11	172.53	13.00	148.15	50.20	25.02	55.40	21.49
Compressor Discharge	87.17	1898.10	86.56	1787.09	188.90	275.30	187.80	259.20
Condenser Inlet	82.91	1898.10	82.39	1787.09	181.24	275.30	180.30	259.20
Condenser Outlet	38.73	1880.04	35.92	1770.97	101.72	272.68	96.65	256.86
Expansion Device Inlet	3.50	1873.28	3.72	1763.65	38.30	271.70	38.70	255.80
Subcooling, at expan. device	5.65		8.35		5.65		8.35	
Evaporator Inlet	3.50	1873.28	3.72	1763.65	38.30	271.70	38.70	255.80
Evaporator Outlet	-25.44	212.33	-19.17	226.12	-13.80	30.80	-2.50	32.80
Evaporator Superheat	6.60		3.78		6.60		3.78	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Low Temp 120° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			1.20	0.89	kg/min	2.64	1.96	lb/min	0.74
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	23.84	24.25	C	74.91	75.65	F	
		wb	17.64	18.05	C	63.75	64.48	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2971.49	2815.12	W	10139.13	9605.60	Btu/hr	0.95
Sensible Capacity					W			Btu/hr	
Total System Power Input			2997.66	2949.35	W	2997.66	2949.35	W	0.98
Compressor Power Input			2650.00	2604.40	W	2650.00	2604.40	W	0.98
Energy Efficiency Ratio (EER)			1.12	1.08	W/W	3.83	3.69	Btuh/W	0.96
Coeff. Of Performance (COP)			3.20	4.65					1.45

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio – SEER			
Heating Seasonal Performance Factor – HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	-19.11	-17.09	C	-2.41	1.24	F	
Outlet Temperature	-24.30	-22.15	C	-11.73	-7.87	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	25.66	23.60	C	78.18	74.47	F	
Outlet Temperature	48.44	48.21	C	119.19	118.77	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	13.11	180.21	15.50	152.71	55.60	26.14	59.90	22.15
Compressor Discharge	87.50	2248.65	86.94	2156.65	189.50	326.14	188.50	312.80
Condenser Inlet	84.04	2248.65	83.06	2156.65	183.27	326.14	181.51	312.80
Condenser Outlet	46.05	2232.31	43.72	2144.55	114.90	323.77	110.70	311.04
Expansion Device Inlet	8.33	2216.64	8.00	2130.45	47.00	321.50	46.40	309.00
Subcooling, at expan. device	5.48		8.28		5.48		8.28	
Evaporator Inlet	8.33	2216.64	8.00	2130.45	47.00	321.50	46.40	309.00
Evaporator Outlet	-24.06	226.81	-16.83	241.98	-11.30	32.90	1.70	35.10
Evaporator Superheat	6.54		5.06		6.54		5.06	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Appendix B:

Medium Temperature Data

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Medium Temp 70° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			3.04	2.28	kg/min	6.69	5.03	lb/min	0.75
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.32	24.26	C	75.77	75.68	F	
		wb	18.46	18.38	C	65.23	65.09	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2268.83	2279.57	W	7741.57	7778.23	Btu/hr	1.00
Sensible Capacity					W			Btu/hr	
Total System Power Input			2391.50	2222.29	W	2391.50	2222.29	W	0.93
Compressor Power Input			2049.80	1885.80	W	2049.80	1885.80	W	0.92
Energy Efficiency Ratio (EER)			1.11	1.21	W/W	3.78	4.12	Btuh/W	1.09
Coeff. Of Performance (COP)			1.19	1.30					1.09

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio - SEER			
Heating Seasonal Performance Factor - HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	0.83	0.38	C	33.49	32.69	F	
Outlet Temperature	-3.81	-4.67	C	25.15	23.59	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	16.08	15.93	C	60.94	60.68	F	
Outlet Temperature	19.09	19.10	C	66.36	66.38	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	19.38	442.65	15.66	377.21	66.89	64.20	60.20	54.71
Compressor Discharge	67.98	1168.02	75.44	1117.99	154.36	169.41	167.79	162.15
Condenser Inlet	65.28	1168.02	71.88	1117.99	149.50	169.41	161.38	162.15
Condenser Outlet	19.45	1136.55	17.62	1092.34	67.02	164.84	63.71	158.43
Expansion Device Inlet	3.63	1137.44	3.33	1092.33	38.53	164.97	38.00	158.43
Subcooling, at expan. device	5.89		13.78		5.89		13.78	
Evaporator Inlet	3.63	1137.44	3.33	1092.33	38.53	164.97	38.00	158.43
Evaporator Outlet	-3.11	483.92	-3.08	406.55	26.39	70.19	26.46	58.97
Evaporator Superheat	6.60		6.27		6.60		6.27	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Medium Temp 90° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			3.04	2.28	kg/min	6.69	5.03	lb/min	0.75
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.32	24.26	C	75.77	75.68	F	
		wb	18.46	18.38	C	65.23	65.09	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2268.83	2279.57	W	7741.57	7778.23	Btu/hr	1.00
Sensible Capacity					W			Btu/hr	
Total System Power Input			2564.69	2484.18	W	2564.69	2484.18	W	0.97
Compressor Power Input			2049.80	1885.80	W	2049.80	1885.80	W	0.92
Energy Efficiency Ratio (EER)			1.11	1.21	W/W	3.78	4.12	Btuh/W	1.09
Coeff. Of Performance (COP)			1.19	1.30					1.09

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio - SEER			
Heating Seasonal Performance Factor - HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	0.26	2.14	C	32.46	35.86	F	
Outlet Temperature	-4.29	-3.77	C	24.27	25.22	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	24.92	26.48	C	76.86	79.67	F	
Outlet Temperature	29.56	29.15	C	85.21	84.48	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	18.56	429.75	15.77	381.18	65.40	62.33	60.38	55.29
Compressor Discharge	75.81	1517.10	84.61	1493.00	168.46	220.04	184.30	216.54
Condenser Inlet	72.69	1517.10	80.49	1493.00	162.83	220.04	176.89	216.54
Condenser Outlet	29.74	1490.79	28.36	1470.05	85.53	216.22	83.05	213.21
Expansion Device Inlet	5.84	1487.35	6.14	1467.93	42.52	215.72	43.05	212.91
Subcooling, at expan. device	5.43		13.57		5.43		13.57	
Evaporator Inlet	5.84	1487.35	6.14	1467.93	42.52	215.72	43.05	212.91
Evaporator Outlet	-3.91	470.34	-2.66	410.73	24.97	68.22	27.21	59.57
Evaporator Superheat	6.71		6.51		6.71		6.51	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Medium Temp 105° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			3.04	2.28	kg/min	6.69	5.03	lb/min	0.75
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.32	24.26	C	75.77	75.68	F	
		wb	18.46	18.38	C	65.23	65.09	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2268.83	2279.57	W	7741.57	7778.23	Btu/hr	1.00
Sensible Capacity					W			Btu/hr	
Total System Power Input			2839.97	2753.85	W	2839.97	2753.85	W	0.97
Compressor Power Input			2049.80	1885.80	W	2049.80	1885.80	W	0.92
Energy Efficiency Ratio (EER)			1.11	1.21	W/W	3.78	4.12	Btuh/W	1.09
Coeff. Of Performance (COP)			1.19	1.30					1.09

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio - SEER			
Heating Seasonal Performance Factor - HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	0.91	-0.10	C	33.64	31.82	F	
Outlet Temperature	-3.63	-5.53	C	25.46	22.04	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	25.40	25.28	C	77.73	77.50	F	
Outlet Temperature	39.33	37.42	C	102.80	99.36	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	19.26	444.57	15.13	361.85	66.66	64.48	59.23	52.48
Compressor Discharge	83.43	1856.78	85.59	1791.22	182.18	269.30	186.07	259.79
Condenser Inlet	80.23	1856.78	81.45	1791.22	176.42	269.30	178.61	259.79
Condenser Outlet	38.05	1830.11	34.42	1769.20	100.49	265.44	93.95	256.60
Expansion Device Inlet	9.13	1823.27	7.25	1766.09	48.44	264.44	45.06	256.15
Subcooling, at expan. device	5.23		15.39		5.23		15.39	
Evaporator Inlet	9.13	1823.27	7.25	1766.09	48.44	264.44	45.06	256.15
Evaporator Outlet	-3.07	486.22	-3.96	389.14	26.47	70.52	24.87	56.44
Evaporator Superheat	6.42		6.87		6.42		6.87	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Hussmann Manufacturer's Notation:

Basic Information	Medium Temp 120° Condensing
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40c
Alternative Lubricant Type and ISO Viscosity	Polyolester
Baseline Refrigerant and Lubricant	R-404A Polyolester
Make and Model of System	ZF09K4E-TF5
Nominal Capacity and Type of System	9260

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Scroll	Scroll					
Compressor Displacement			0.16	0.16	m^3/min	5.71	5.71	ft ^3min	1
Nominal Motor Size			3	3	hp				1
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.45	1.45	kg	3.19	3.19	lb	1
Refrigerant Charge			7.94	7.94	kg	17.5	17.5	lb	1
Refrigerant Mass Flow Rate			2.91	2.23	kg/min	6.42	4.92	lb/min	0.77
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	24.19	24.17	C	75.54	75.51	F	
		wb	18.35	18.50	C	65.04	65.29	F	
	Outdoor	db			C			F	
		wb			C			F	
Total Capacity			2510.15	2364.06	W	8564.97	8066.52	Btu/hr	0.94
Sensible Capacity					W			Btu/hr	
Total System Power Input			3241.23	3148.32	W	3241.23	3148.32	W	0.97
Compressor Power Input			2902.00	2802.10	W	2902.00	2802.10	W	0.97
Energy Efficiency Ratio (EER)			0.86	0.84	W/W	2.95	2.88	Btuh/W	0.98
Coeff. Of Performance (COP)			1.17	1.42					1.22

Other System Changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd			
Seasonal Energy Efficiency Ratio - SEER			
Heating Seasonal Performance Factor - HSPF			

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Display Cabinet (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	0.25	0.09	C	32.44	32.16	F	
Outlet Temperature	-4.56	-5.01	C	23.79	22.98	F	
Condenser							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^3/min			ft ^3/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	24.97	24.12	C	76.95	75.41	F	
Outlet Temperature	50.46	49.43	C	122.82	120.97	F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	18.29	431.69	14.94	372.86	64.92	62.61	58.89	54.08
Compressor Discharge	86.07	2279.41	86.05	2151.08	186.93	330.60	186.89	311.99
Condenser Inlet	83.34	2279.41	82.28	2151.08	182.01	330.60	180.11	311.99
Condenser Outlet	46.64	2250.65	40.72	2128.88	115.95	326.43	105.30	308.77
Expansion Device Inlet	10.61	2238.42	9.60	2120.16	51.10	324.66	49.29	307.50
Subcooling, at expan. device	5.49		17.37		5.49		17.37	
Evaporator Inlet	10.61	2238.42	9.60	2120.16	51.10	324.66	49.29	307.50
Evaporator Outlet	-4.15	470.47	-3.52	399.92	24.53	68.24	25.67	58.00
Evaporator Superheat	-14.30		-14.27		6.25		6.31	

Data Source(s) for Refrigerant Properties
REFPROP 9.1

Additional Notes

Submitted by: Paul Laurentius

Appendix C:

Low Temperature Summary Data

Temperature application	Low Temp Applications							
Condensing temperature	120		105		90		70	
Refrigerant	R-404A	N40c	R-404A	N40c	R-404A	N40c	R-404A	N40c
Subcooling (°F)	5.2	4.5	5.3	3.4	4.5	5.3	4.2	4.9
Front Evaporator Superheat (R)	6.3	5.3	6.6	3.8	5.8	6.5	6.4	4.5
Rear Evaporator Superheat (R)	6.8	4.9	6.6	3.8	6.6	6.0	6.4	4.3
Average Superheat	6.5	5.1	6.6	3.8	6.2	6.2	6.4	4.4
Q evap	10139.1	9605.6	10088.2	9655.3	10589.8	10287.5	11007.8	9018.9
Q comp	3168.4	2064.6	3410.2	2340.7	3394.0	2656.0	3465.7	2522.8
Q cond	-10816.9	-8243.5	-11222.1	-8908.0	-11038.1	703.8	-11428.1	-9427.7
Energy balance residual	2490.6	3426.7	2276.3	3088.0	2945.7	3359.8	3045.4	2114.0
Integrated Product Average (°F)	2.0	5.5	-0.2	2.6	-0.1	0.6	1.2	2.4
Mass Flow Compressor Suction (lb/hr)	158.3	117.6	149.5	115.1	135.0	115.0	129.3	101.3
Mass Flow Liquid Injection (lb/hr)	75.5	73.7	45.1	48.7	19.6	28.1	4.7	10.7
COP (Q ref / Comp W)	1.1	1.1	1.3	1.3	1.7	1.7	2.2	2.0
Average Compressor Power (W)	2650.0	2604.4	2191.0	2127.3	1780.0	1788.1	1443.2	1346.0
Air Discharge Temperature (°F)	-12.3	-8.1	-14.1	-11.7	-12.2	-13.4	-13.1	-11.9
Compressor Discharge Temperature (°F)	189.5	188.5	188.9	187.8	188.0	187.1	185.4	186.7
Compressor Suction Temperature (°F)	55.6	59.9	50.2	55.4	47.1	49.4	43.8	49.0
Compressor Discharge Pressure (psia)	326.1	312.8	275.3	259.2	222.4	213.3	172.3	154.5
Compressor Suction Pressure (psia)	32.9	35.1	33.5	32.8	30.3	25.1	30.3	32.9
Evaporator temperature (°F)	-16.9	-11.3	-16.1	-14.3	-20.6	-25.8	-20.6	-14.2
Compressor lift (psid)	300.0	290.6	250.3	237.7	196.0	191.0	145.8	135.9
Pressure ratio	12.5	14.1	11.0	12.1	8.4	9.5	6.5	8.3
Calculated Thermodynamic COP (Q evap / Q Comp)	3.2	4.7	3.0	4.1	3.1	3.9	3.2	3.6
Dry Bulb	74.9	75.6	75.3	75.8	75.2	75.0	75.2	75.9
Wet Bulb	63.8	64.5	64.2	64.3	64.1	63.6	65.6	64.3

Appendix D:

Medium Temperature Summary Data

Temperature application	Medium Temp Applications							
Condensing temperature	120		105		90		70	
Refrigerant	R-404A	N40c	R-404A	N40c	R-404A	N40c	R-404A	N40c
Subcooling (°F)	3.6	13.5	3.2	11.2	3.2	9.1	3.2	9.0
Front Evaporator Superheat (R)	6.2	6.0	6.6	6.9	7.0	6.4	6.6	6.2
Rear Evaporator Superheat (R)	6.3	6.6	6.2	6.9	6.4	6.6	6.6	6.3
Average Superheat	6.3	6.3	6.4	6.9	6.7	6.5	6.6	6.3
Q evap	8565.0	8066.5	8040.4	7925.1	7966.7	7730.0	7741.6	7778.2
Q comp	7332.5	5667.3	7868.6	5949.4	7034.2	6596.8	6487.5	5986.2
Q cond	-25954.0	-21233.5	-29635.1	-22216.9	-30475.3	-24989.3	-33615.0	-26597.9
Energy balance residual	-10056.5	-7499.7	-13726.1	-8342.5	-15474.4	-10662.6	-19385.9	-12833.4
Integrated Product Average (°F)	33.0	33.1	34.9	32.2	33.5	33.7	33.7	33.3
Mass Flow Compressor Suction (lb/hr)	385.5	295.0	398.1	284.9	388.6	300.4	401.7	301.8
Mass Flow Liquid Injection (lb/hr)	26.6	37.8	0.6	17.9	0.0	1.9	3.6	1.9
COP (Q ref / Comp W)	0.9	0.8	0.9	1.0	1.1	1.1	1.1	1.2
Average Compressor Power (W)	2902.0	2802.1	2499.0	2410.8	2223.3	2139.7	2049.8	1885.8
Air Discharge Temperature (°F)	23.9	23.2	25.3	22.1	23.9	24.9	24.9	23.5
Compressor Discharge Temperature (°F)	186.9	186.9	182.2	186.1	168.5	184.3	154.4	167.8
Compressor Suction Temperature (°F)	64.9	58.9	66.7	59.2	65.4	60.4	66.9	60.2
Compressor Discharge Pressure (psia)	330.6	312.0	269.3	259.8	220.0	216.5	169.4	162.2
Compressor Suction Pressure (psia)	62.6	54.1	64.5	52.5	62.3	55.3	64.2	54.7
Evaporator temperature (°F)	14.1	11.3	15.6	9.8	13.9	12.4	15.4	11.9
Compressor lift (psid)	268.0	257.9	204.8	207.3	157.7	161.3	105.2	107.4
Pressure ratio	5.3	5.8	4.2	5.0	3.5	3.9	2.6	3.0
Calculated Thermodynamic COP (Q evap / Q Comp)	1.2	1.4	1.0	1.3	1.1	1.2	1.2	1.3
Dry Bulb	75.5	75.5	75.5	75.6	75.7	74.5	75.8	75.7
Wet Bulb	65.0	65.3	65.3	65.0	65.4	64.2	65.2	65.1